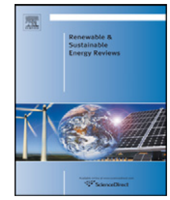
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Renewable energy resources and sustainable development in Mykonos (Greece)

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ABSTRACT

Nowadays, the increase of carbon dioxide emissions contributes to the surface temperature's increase and it is the prime cause for the climatic changes. The basic measure that has been taken by world community for the confrontation of this phenomenon was the use of renewable energy sources (RES).

This research refers to the use of RES, in the island of Mykonos. It focuses on the repercussions of renewable energy sources on the environment as well as the economic sector. Specifically, it refers to the aeolian parks and to the photovoltaic systems of electric energy production. At the same time, the research takes into account the existing legislative regulations for the uses as well as for the spatial planning frames for the RES.

For the exploration of repercussions was used not only the research of elements and that of primary sources but also the methodology of interviews as well as the observation on the spot. The conclusions showed that the correct management of renewable energy sources from regulations of local authorities like the Municipality of Mykonos, as well as the private sector can contribute to the protection of environment and to the economic development of the area.

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1. Introduction

Nowadays, the increase of the environmental problems spread quickly so that the ecological state of planet is threatened. One of the basic environmental problems is the greenhouse gases emission, which causes climatic changes, having unfavorable repercussions on the natural and anthropogenic environment.

The international community has been aware and commits the developed countries to proceed with the reduction of greenhouse gases emissions via the international conventions on the climatic change.

According to the calculations, the European Union, with her 25 member states, is responsible only for the 14% of world's greenhouse gases emissions. Up to now, European Countries' efforts, for the reduction of greenhouse gases emission at 8% during the time period 2008–2012, have achieved essential progress. However, additional national meters are required for the achievement of the objective [1].

The use of renewable energy sources, (such as aeolian, geothermal, solar, hydroelectric, energy derived from airy fuels, biomass as well as other forms of energy), is one of the main factors regarding the reduction of gases emissions that contributes to the

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destruction of ozone and has as consequence the increase in surface temperature.

The European Union has placed as objective the participation rate of the renewable energy sources at 12% on its energy balance from 1997 until 2010 [2]. Particularly, the Union has placed as a goal a rate of 21% regarding the production of electric energy from RES until 2010. At the same time with the European Union, the national objective for electricity generation from RES amounts at 20.1% until 2010 and at 29% by 2020 [3].

However, the development of renewable energy sources in an area depends on many factors, like the sunlight of the area, the aeolian dynamic, the finding of plot, the enactment of land uses that would allow the development of work for RES, the disposal of capital etc.

In Greece, various legislative regulations have been established for the promotion of RES works such as the developmental law 3299/2004 according to which the investment drawings are strengthened concerning the production of Electric Energy derived from renewable energy sources [4], as well as the law 3468/2006 for electric energy production derived from renewable energy sources [6]. In 2006 the RES covered the 11.5% of total production of electric energy with 9.71% stemming from hydroelectric units, 1.5% from aeolian energy and 0.23% from biogas [6]. The photovoltaic systems development constitutes part of promotion program of electric energy production from RES and has duration by 2020 [7].

It is remarkable to say that the regional spatial planning frames should be harmonized according the directions of Special Frames. Consequently the drawings of land uses regulations of General Building Plan (GBP) and of Drawing for Spatial Built-up Organization Open City (DSBOOC) cannot limit the development of RES work that forecasts the Special Frame for the RES [8].

The aeolian potential of the area regarding the aeolian parks, which is a necessary condition, should be $\geq$7.5 m/s during a semester as well as the margin for installation of a new force from production station of electric energy [9]. While, for the development of photovoltaic systems, the land uses should not be in rural area of high output and not be characterized as protected area.

Furthermore, the development of work for renewable energy sources referring to the production of electric energy 20 kW requires the approval of the environmental terms. In case of electric energy production >150 kW it is required a study on environmental repercussions according to arrangement criteria placed by the special land-planning frame for the renewable energy sources [21].

The authorization of electric energy production taken by private individuals can be recalled when it is realized that they stretch the legislative and lawful frame regarding RES's [10], matters, as well

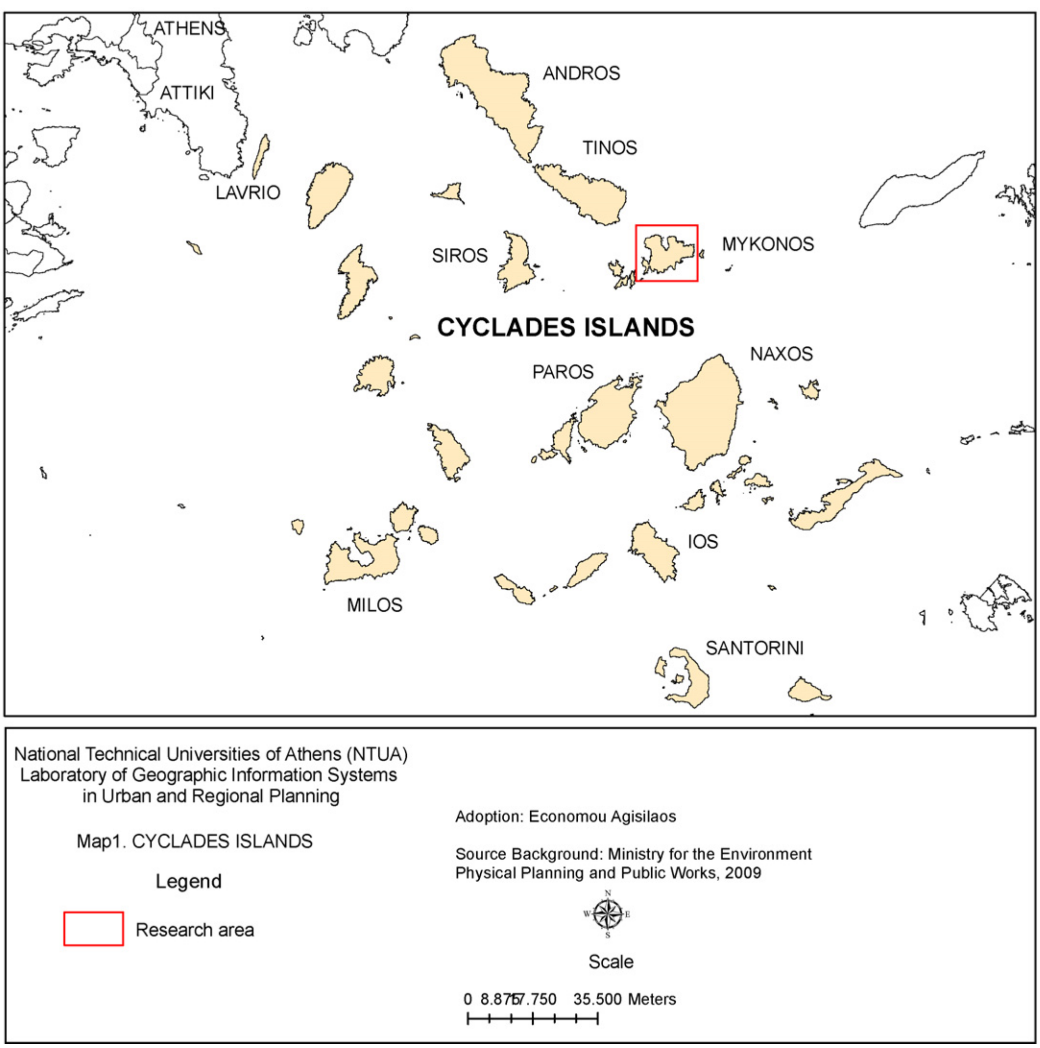


Fig. 1. Research area.

as in case that the authorization of installation has not been granted for three years by the date of issuing the authorization production [6].

Also, the installation of photovoltaic systems is allowed to the roofs of houses as well as to the open area of plots [8].

In regional scale, the sustainable energy development needs organization and application of institutions, action, supports measures etc. However, Municipalities can play a considerable role, in local level, by promoting sustainable energy [5].

2. Case study (Mykonos)

Mykonos has an extent of 105,481 crowns. It belongs to the group of Cyclades Islands and administratively is governed by the prefecture of Southern Aegean (Fig. 1).

The area is hilly, with altitudes (341m in the Prophet Ilias of Ano Meras, Vardies 372 m. and 384m in the Prophet Ilias) [11], and it presents big intensity of winds (10.5 m/s in the region of Prophet Ilias in altitude 30 m, 10.8 m/s in Fanari and 8.9 m/s in the Moroergoy area in altitude 10 m) [12].

Thus, the area can support the construction of aeolian work and the development of photovoltaic systems, respectively, concerning the production of electric energy due to the big intensity of winds and the high sunlight.

Mykonos has limited flora and fauna. The flora is constituted by makkia vegetation, brushwood, and a great number of annual plants. In the area 26 endemic, infrequent and threatened types are thrived. The two coastal water biotopes in the region of bight Panormou of Ftelias present appreciable ecosystems. Also, the area of Moroergou has shelter of preys [11].

The island presents big tourist development during the summer months (615,514 overnight stays in 2001) [13] due to its appreciable natural resources (coasts, beaches, architectural heritage, and entertainment). That has as a result the increase of water and electric power demand. The main electric energy supply of island derives from National Electrical Company (NEC) (10.88 MW) via electricity output pairs ([E]/[P]) having as main fuel the oil [14]. Generally, in the area of Mykonos, the NEC allocates 20 machines of 38.4 MW power in periods of high demand (peak period) [15].

With regard to RES, two types of RES are used in the island, the solar energy (due to high sunlight) and the aeolian energy (due to winds).

Today, only the wind generator of Municipal Enterprises for Water Supply and Sewerage (MEWSS) is in function. It is placed in the Dam of Ano Meras, in the place of Maou (Fig. 2), where the use of produced Electric Energy, for the operation of desalination factory, is necessary. The work took place according the Program THERMIE's framework of European Union, in collaboration with the Center of RES [12].

3. Data and methods

For the information feedback regarding the RES, geographical data was used as well as data for climate conditions such as the

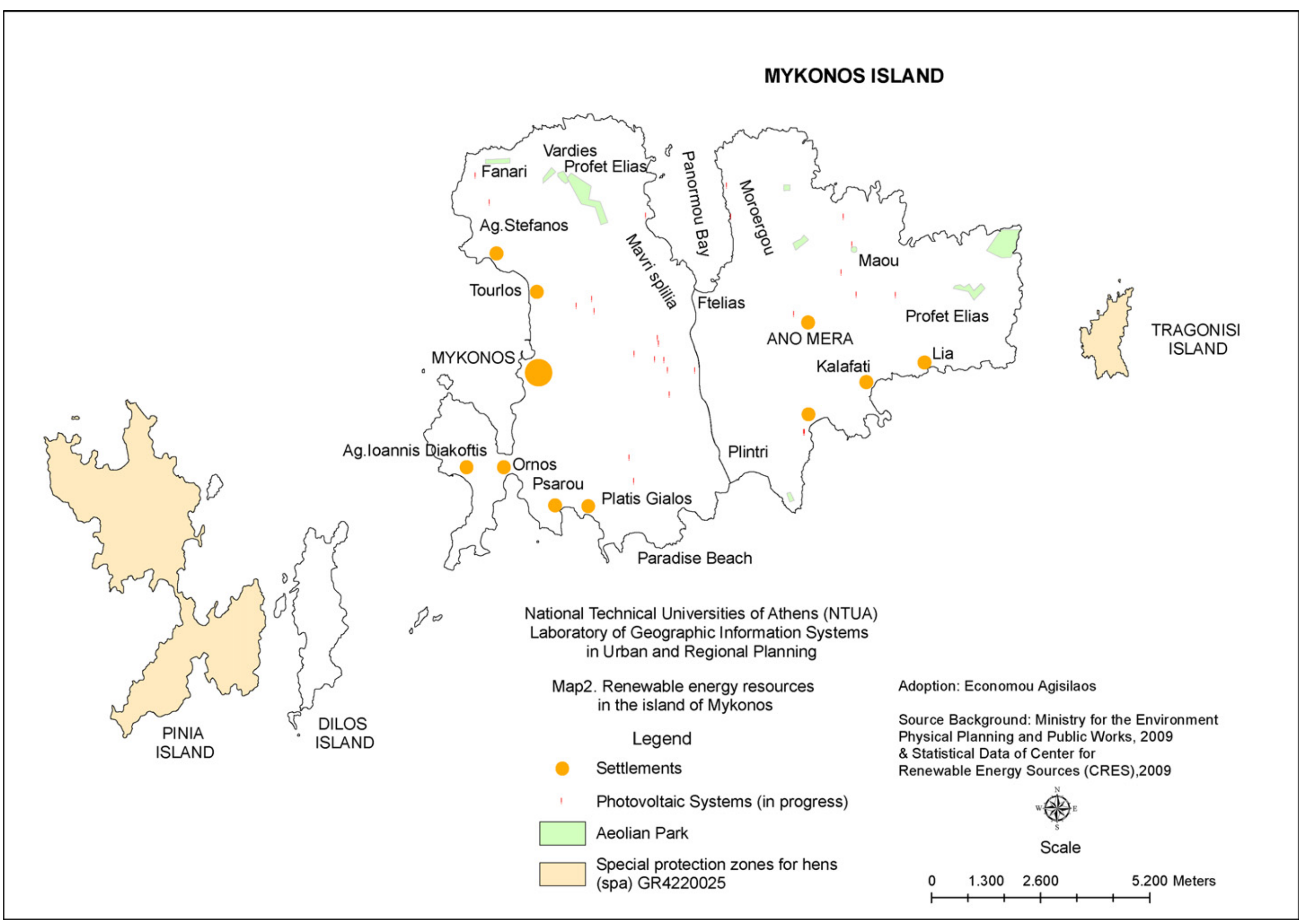


Fig. 2. Renewable energy resources map in the island of Mykonos.

sunlight and the wind intensity. In addition, data is collected from services which are involved in the production of electric power.

Moreover, researches and legislative drafts for the development of RES, the regulation of land uses via spatial planning, as well as the directive of EU were used. In addition to this, a personal interview with the engineering service of municipality took place. Particularly, the research regarding the use of the green energy, focused on the types of RES that are used in the island, on municipality's repercussions and potentials as well as on private sector taking as a goal the sustainable development.

The creation of maps is achieved by taking data from the Geographic Information Systems (GIS). The topographic diagrams and the land use maps provided information regarding the geographical data. Also, there are used programmes concerning the calculation of sunlight radioactive in the area of Mykonos and the photovoltaic systems output such as the RETScreen, the Photovoltaic Geographic Systems of European Commission as well as programmes of American Forest for calculations of carbon dioxide.

4. Research and results

The research in area of Mykonos for the RES showed that:

- The RES that are used in the island of Mykonos are the aeolian parks. Those are the air turbine of MEWSS and that of one private person (power 1 MW). The air turbine of MEWSS took place based on spatial and aesthetic criteria for the reduction of the environmental repercussions.
- During the construction of the first private air turbine, problems of social reaction are arouse caused by proprietors that handle tourist areas having as a result the activities' delay for six years. On the contrary, in case of MEWSS, the construction of works was accepted from the local communities. Moreover, problems of clearance were not existed due to participation of Center for Renewable Energy Sources (CRES), so the work was proceeded without the installation and operation licence that is provided for in law 2244/94 [22].
- The plan of Municipalities includes the continuation of aeolian park's operation of MEWSS and its extension, the construction of other aeolian parks, as well as the development of other RES, especially the photovoltaic systems.
- The increase of demand regarding the authorization and the electric power supply from photovoltaic systems as well as from other aeolian parks derived from the private sector. More specifically, in the area of Mykonos there are clearances for 5 air turbines of total power 6 MW, while the applications for the development of photovoltaic systems of total power 5.14 MW are in progress (Fig. 2). It is underlined that the Public Power Corporation (PPC) S.A. has the authorization for the development of an aeolian park for electric energy production of 1.8 MW [16].
- It is expected that the specific developing photovoltaic program system till 10 kWp, concerning building constructions used for residence or establishment of small enterprises, to contribute to the electric power production for the covering of buildings' energy necessities [17].
- During the authorization of RES, many organizations take place resulting to the retardation of clearances.

4.1. Other actions

At the same time the construction of substation of 150/20 kV (closed type) in Mykonos and the interconnections with the island of Paros and Syros with the Center of High Tendency of Lavrion (Athens) with cables of alternating current were decided. The works will be finished by 2012 [16]. With the realization of work the PPC expects the guarantee of sufficient quantity of electric energy in the area of Mykonos.

5. Discussion

The development of work, as far as the use of renewable energy sources is concerned, is realized according to the International Convention – Frame for the climatic change. That refers to the commitment of developed countries for reduction of greenhouse gases emissions, as well as the objectives set by the European Union and Greece regarding the production of electric energy from RES. However, the development of work of RES has different consequences on the economic sector as well as on the natural environment.

5.1. Economic repercussions

According to the current legislation, the development of renewable energy sources, except that of photovoltaic systems, is charged with special rates 3% on the total VAT, which is the sale price of electric energy of the System Administrator, or of non-interconnecting network of islands. The 80% of special rates is disposed in the Municipality's area for the implementation of local work development in areas which their limits are within the municipal or community region and where the station is installed, or the line of connection goes through, while the rest 20% is disposed to the rest of prefecture [6].

In case of wind generator of MEWSS the economic evaluation of CRES [12] judged that the investment of work was positive even in the case of total Greek Investment (15% of work it was financed by the Greek State via CRES). More specifically: the wind generator of MEWSS, during the operation for the years 2004–2008, has produced 4,992,635.58 kWh yielding 429,127.27 Euros (Table 1). Taking into account the cost of work that amounts to 484,255 Euros (40% financed by the European Union, and 15% by CRES), the cost of maintenance (2300 Euro plus 13% of VAT for a half of year), other expenses of operation (1000 Euros/year), the cost of damage and deteriorations (40,000 Euros up to today), as well as the cost for land 30X2934.70 euro/acres [12], it results a positive economic profit for the MEWSS about 14,428.62 Euros.

5.2. Environmental repercussions

The environmental repercussions of work RES in the area of Mykonos do not bring about important consequences in the environment. In general, the electric energy production installations from RES are characterized as non-intrusive installations [8]. The wind generators' repercussions are the increase of noise level and the optical alteration of landscape. The noise level caused by a wind turbine of 100 dB (A), reaches a noise level of 45 dB(A) in a distance of 141 m [18].

Table 1
Energy production, economic and environmental profits for the wind generator of MEWSS [12,20].

Year	Production (kWh)	Value (Euro)	Annual education of CO_2 emissions (tons)	Annual number of new trees that would be needed for the absorption of CO_2
2004	997,739.58	79,189.76	748.30	2244.9
2005	750,996	62,631.86	563.20	1689.7
2006	1,193,280	98,973.24	895.00	2684.9
2007	1,105,800	100,750.45	824.40	2488.1
2008	944,820	87,581.96	708.60	2125.8
Total	4,992,635.58	429,127.27	3739.50	11,233.4

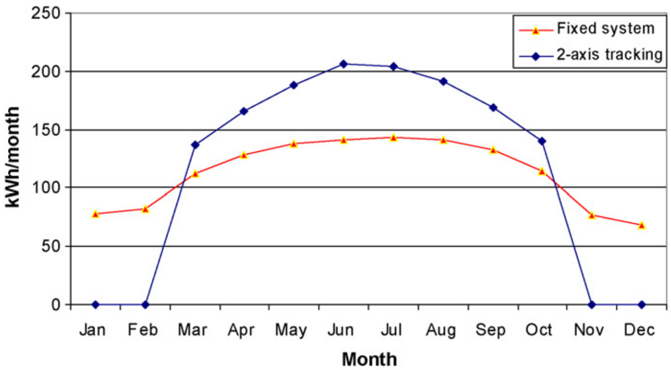


Fig. 3. Average monthly electricity production from the given system (kWh) [19] (fixed system: inclination = 35°, orientation = 0°; power of the PV system: 1 kW (crystalline silicon); estimated losses due to temperature: 10.4% (using local ambient temperature); estimated losses due to angular reflectance effects: 2.5%; other losses (cables, inverter): 14.0%).

In addition, the photovoltaic systems as well as the wind generators, after the operation completion can be dismantled restoring the optical alteration of the environment. Moreover, that constitutes obligation of approved environmental terms regarding the operation of electric energy production installations from RES [8].

During the period of operation, the work contributes to the reduction of greenhouse gases emissions. Concretely, during the time period 2004–2008 the wind generator of MEWSS has produced 4,992,635.58 kWh, meaning reduction of carbon dioxide (CO_2) emission at 3739.50 tons or 11,233.4 trees that would be needed for its absorption (Table 1) [12,20].

In Mykonos, a photovoltaic system of 1 kW (crystalline silicon) with an inclination 35° produces roughly 1350 kWh/year, or 1770 kWh/year with 2-axis tracking system (Figs. 3 and 4) [19]. Consequently, the photovoltaic systems of 5.14 MW can produce respectively 6,939,000 kWh/year meaning reduction of CO_2 emission in 5204.2 tons or 15,613 trees that it would be needed for its absorption. In that case that the photovoltaic systems are with 2-axis tracking system the production would be 9,097,800 kWh/year which corresponds to 6823.4 tons of CO_2 or 20,470 trees that it would be needed for its absorption [20].

5.3. Carrying capacity and place arrangement of RES

The maximum number of wind generators is 55.9 in the area of Mykonos, taking into account the carrying capacity of island, needed for the development of aeolian parks which is 4% of Municipality's extent or 0.53 formal wind generators/1000 acres

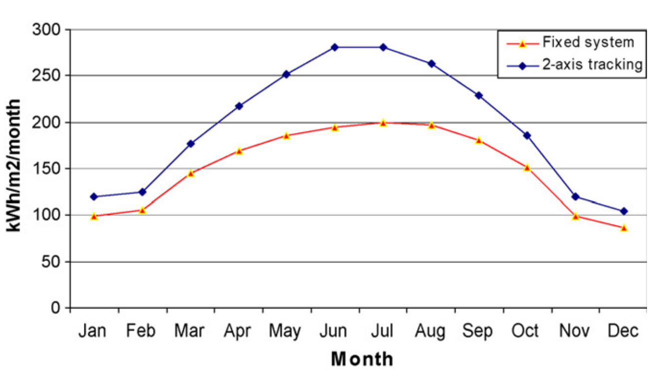


Fig. 4. Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2) [19].

[8]. On the other hand, the development of aeolian parks in the area of Mykonos is limited even more taking into account that the total force of aeolian stations should not exceed the double level of demand in peak periods as well as the existing area that allows the construction of aeolian parks.

Regarding the photovoltaic systems, the required extent for their development depends on the size panel, its inclination and its distance from neighboring panels as well as on the technology that is used. For example, the use of monocrystalline photovoltaic systems of high efficiency per each 1 kW, in an inclined surface, requires 8–10 m^2 [21]. Thus, if the development of photovoltaic system of 1 kW requires an extent of 9 m^2, on average, the development of the demanding 5.14 MW will require an extent of 46.26 acres meaning the 0.04% Municipality's extent.

According to the Built-up Zone Control of Mykonos the development of photovoltaic systems can be realized only in the industrial zone. However, the areas that belong to industrial zone do not coincide with those of high potential. Thus, the Special Frame regarding the area of Mykonos requires the modification of relative Presidential Decree in the Built-up Zone Control for potential RES installations' arrangement in agricultural areas as well as in areas of concentrated processing and storage installation [8].

6. Conclusions

The area of Mykonos favors the development and expansion of RES due to the high level of the sunlight and wind.

Regarding the environment protection, the aeolian parks that operate in island contribute, to a small percentage, to the decrease of the carbon dioxide in atmosphere. Consequently, they contribute to the confrontation of green house effect that causes climate changes in planet.

As far as the economical sector is concerned, the RES strengthens the proprietors' economic potential as well as the Municipality regarding the infrastructure. At the same time, the RES supports the area with electric power, which its demand is increasing due to the intensive tourist activity during the summer months.

The development of photovoltaic systems is in progress and it is expected that they will contribute, in a considerable way, to the increase of electric power production, to the environment protection as well as to the economical growth of the area. However, the development of photovoltaic systems as well as the construction of new aeolian parks should take into account the carrying capacity of the island and the aesthetic degradation of landscape. At the same time, they should implement the new measures as regard to the place arrangement of works according to Special Regional Planning for the renewable energy sources.

The goals of European Union's directive regarding the permeation of RES are achieved by the amplification of aeolian parks' electric power in network, via the photovoltaic systems, as well as by the development of photovoltaic systems in roofs and plots.

To sum up, we conclude that the RES that have been developed in Mykonos contribute, to a small extent, to the environment protection as well as to the economic growth of the area. The development and the other types of RES such as the photovoltaic systems expect to have positive results in island. Also, the research shows the energetic role that can have the local authority as well as the private sector for the confrontation of the environmental problems, such as the green house effect via the renewable energy sources. Moreover, the area of Mykonos not only can cover all the energetic needs from RES, if it will exploit the RES in full, but also supply other islands with electric power.

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